

FEASIBILITY OF MULTI-ON-ONE EFFECTIVENESS STUDY

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A study is underway to determine the effectiveness of a group of interceptors against a single target. The first phase of the study is a discussion of the multi-on-one attack profiles and the recommended methods of estimating the probability of killing the target given the attack formation and profile. The solutions will vary among the different formations since in closed formations the actions of the pilots will be strongly dependent upon the actions of the other pilots in formation, whereas in open formations the actions of the pilots are substantially independent of the actions of the other pilots in formation.

The one-on-one attack effectiveness model can be modified to make the study. By appropriately selecting the input parameters and by appropriately combining the trial outcomes of the one-on-one model, the estimates of multi-on-one effectiveness can be determined. The modifications that are recommended to be made internal to the one-on-one model to make it compatible with the results that are needed for determining the multiple-on-one effectiveness are minimal and feasible.

A subprogram will be added to the one-on-one model. A set of input control parameters will define the attack type of interest. The subprogram will control the trial inputs and will combine the trial outputs for the group of interceptors. The program will accept up to four interceptors in formation. A byproduct of the multiple-on-one attack case will be the kill probabilities for all formations which are subsets of the input formation. A simplified flow diagram for this subprogram for a pair attack is shown in Figure 1. Each of the blocks 1 through 6 in Figure 1 are discussed subsequently. The subprogram will be generated such that categories 1, 2 and 4 can be added with a minimum of effort at a later date.

Following is a list of items that have been considered in the analysis which led to the six methods for estimating the probability of kill.

1. Types and number of sensors
2. Distance and sighting angles between interceptors at rollout
3. Vectoring errors
4. Simultaneous or sequential attack and firing
5. Ability of pilots to stay in formation
6. Communication between pilots
7. Does tactic imply that interceptors stay in formation?
8. Antenna scan volume
9. Fixed or variable scan?
10. Reliability of missile is less than 1.
11. All interceptors are equipped with the same number and types of missiles.

The treatment of some of the above items does not show up in the logic diagram of Figure 1 but will be discussed under the pertinent attack formation categories. It should be also noted that the discussion of the attack types are confined to pair attacks but solutions can be generalized.

The one-on-one air to air attack effectiveness model is a Monte Carlo simulation. A case consists of N_T attack trials, the outcome of an attack being a success or a failure of the interceptor to fire within the impact zone. Each stochastic variable in the execution of an attack is selected randomly from the appropriate probability distribution. The probability of success is then taken as the ratio of the number of successes to the total number of trials.

$$P_L = \frac{N_L}{N_T} \quad (1)$$

where P_L = the probability of a successful conversion
 N_L = the number of successful conversions
 N_T = the number of trials

The vectoring errors at the initiation of the attack are stochastic variables which are considered in the Monte Carlo simulation. If a formation of interceptors are vectored out to attack by the G. C. I., the vectoring errors on the individual interceptors will be equal. This is simulated in the model by correlating the vectoring errors on the aircraft in formation on each trial and combining the outcomes trial for trial.

I. Simultaneous Attack

A. Closed Formation

Vectoring commands are executed by the leading aircraft and the following aircraft keeps its place in tactical formation about 50 m. above or below the leading aircraft. As soon as one pilot has detected the target he reports "I see" which is a simultaneous sign for the other pilot of the pair, to follow him and execute the approach maneuver against the target or attack same. This implies that even after detection by one or both of the aircraft, the formation is only changed slightly throughout the remainder of the attack.

Given that the vectoring errors in position are in the range of 3-15 n.m. with a nominal rollout range of 25-30 n.m., the distance between the interceptors is negligible (.1-.2 n.m.). As long as the scan angle of the following aircraft sensor is less than the sighting angle to the lead aircraft and the following aircraft is able to keep his place in formation through visual observation of the lead aircraft, there is no interference in the sensor detection of the target. Since the distance between the aircraft is negligible with respect to the vectoring error, range to target and maximum launch range the formation may be treated as a single aircraft with 2 radars searching the same volume (applicable for fixed dish and analogous to having half the scan time of a single sensor) or, if the antenna axes are variable, as a single aircraft with one sensor searching a larger volume of space.

The execution of group attacks at supersonic speeds becomes difficult, particularly at altitudes of more than 15,000 m. because the conditions of maintaining the tactical formation of the attackers are reduced considerably. If the formation is not maintained the attacks on the target by the individual fighters in the group will not be dependent upon the actions of the other fighters and each will have effectively the same probability of launching, since the rollout points are substantially the same.

1) Simultaneous Launch

Given that the pair of fighters maintains formation, the probability of killing the target for the formation is

$$P_{K_F} = P_{L_F} P_{K/L} + [1 - P_{K/L}] P_{K/L} \quad (2)$$

where P_{L_F} = is the probability that the formation converts successfully. One case is run on the one-on-one model utilizing the enhanced detection capability of the formation to estimate P_{L_F}

$P_{K/L}$ = probability of kill given conversion. If one missile is fired from an aircraft $P_{K/L}$ is the reliability (R) of the missile. If more than one missile is fired $P_{K/L} = 1 - (1 - R)^{N_M}$ where N_M = the number of missiles in a volley.

If the pair of fighters does not maintain formation, the probability of killing the target is given by

$$P_{L_{NF}} = \frac{1}{N_T} \sum_{i=1}^{N_T} P_{K_{T_i}} \quad (3)$$

where $P_{K_{T_i}}$ = the probability of killing the target on the i^{th} trial

$$P_{K_{T_i}} = X_{1_i} P_{K/L} + (1 - X_{1_i} P_{K/L}) X_{2_i} P_{K/L} \quad (4)$$

where X_{j_i} = 1 if j^{th} interceptor converted on the i^{th} trial
 = 0 if j^{th} interceptor did not convert on i^{th} trial

On each trial X_{1_i} and X_{2_i} are determined using the same initial attack conditions. Other stochastic variables are selected independently but from the same distributions.

The probability of killing the target is then

$$P_K = P_{SF} P_{KF} + [1 - P_{SF}] P_{K_{NF}} \quad (5)$$

where P_{SF} = the probability that the formation is maintained

It should be noted that since P_{K_F} in general would be greater than $P_{K_{NF}}$, the upper bound on this equation is obtained when the probability of sustaining formation is 1.

$$P_K = P_{K_F} \quad (6)$$

This is a good approximation also if P_{SF} is close to 1 or if P_{K_F} is not substantially greater than $P_{K_{NF}}$, (considering confidence intervals on P_{K_F} and $P_{K_{NF}}$ estimates).

2) Sequential Launches

This tactic requires a modification to the program to take into account the time between missile firings. On each trial in which the formation converts $X'_1 = 1$. The aircraft continues to steer out error until a time interval has elapsed which is sufficient for the preceding aircraft to pull out from attack and X'_2 is determined based upon whether or not the aircraft is in the impact zone after the time lag.

The probability of kill on a trial given that the formation is sustained is then

$$P_{K_{TL}} = X'_1 P_{K/I} + [1 - X'_1] X'_2 P_{K/I} \quad (7)$$

where the primes (') denote that enhanced detection capability was used

$$P_{K_F} = \frac{1}{N_T} \sum_{i=1}^{N_T} P'_{K_{T_i}} \quad (8)$$

The probability of kill given that formation was not sustained is given by equation 3. Two additional runs are necessary to compute equation 3.

The probability of kill is again

$$P_K = P_{SF} P_{K_F} + (1 - P_{SF}) P_{K_{NF}} \quad (9)$$

B. Open Formation

This formation is recommended against maneuvering targets. With properly selected distance between fighters the target is reliably attacked by one of the fighters, regardless of its turn. The magnitude of the distance between the fighters in pair is determined in relation to the vectoring side errors. The distance between the fighters is large compared to the vectoring errors, however, the vectoring errors at rollout are the same. The interceptors actions will be considered independent from rollout. Run two cases, one for each fighter but retain trial outcomes (X_{j_i}). Two modifications to the one-on-one model are required here (1) retaining trial outcomes and (2) correlating vectoring errors at rollout. For each trial the probability of killing the target is

$$P_{K_{T_i}} = X_{1_i} P_{K/L} + X_{2_i} [1 - X_{1_i} P_{K/L}] P_{K/L}$$

where

$$X_{ji} = \begin{cases} 1 & \text{if } j^{\text{th}} \text{ fighter converted to launch on } i^{\text{th}} \text{ trial} \\ 0 & \text{if } j^{\text{th}} \text{ fighter did not convert to launch on } i^{\text{th}} \text{ trial} \end{cases}$$

Then

$$P_K = \frac{\sum_{i=1}^{N_T} P_{K_{Ti}}}{N_T}$$

II Sequential Attack

The sequential attack type has been broken up into three subclasses since the time of flight at the ceiling is critical.

A. Fighters follow same flight path

In this case fighter 2 must maintain ceiling for a longer period of time than fighter 1.

$$T_{Z_2} = T_{Z_1} + \frac{d}{V_2}$$

where

T_{Z_2} = time at which fighter 2 initiates zoom

T_{Z_1} = time at which fighter 1 initiates zoom

d = distance between fighters

V_2 = velocity of fighter 2

$$R_{Z_2} = R_{Z_1} - \Delta V \frac{d}{V_2}$$

where

R_{Z_2} = range between fighter 2 and target at T_{Z_2}

R_{Z_1} = range between fighter 1 and target at T_{Z_1}

ΔV = rate of overtake of target

Assume that if formation is maintained, detection capability of formation is enhanced and errors on R_Z are correlated.

Run case for each fighter with same vectoring and R_Z errors. Initial positions and R_Z 's are different. Retain trial outcomes.

$$P'_{K_{T_i}} = X'_{1K/L} P_{K/L} + (1 - X'_{1K/L}) X'_{2i} P_{K/L}$$

Run case for each fighter (assuming formation not maintained) with single fighter detection capability and uncorrelated errors on R_Z but R_{Z_1} is still different from R_{Z_2} . Again retain trial outcomes.

$$P_{K_{T_i}} = X_{1i} P_{K/L} + (1 - X_{1i}) X_{2i} P_{K/L}$$

The probability of killing the target is then

$$P_K = P_{SF} \frac{\sum_{i=1}^{N_T} P'_{K_{T_i}}}{N_T} + [1 - P_{SF}] \frac{\sum_{i=1}^{N_T} P_{K_{T_i}}}{N_T}$$

B. Zoom at same distance from target

In this case in general each fighter would be at the flight ceiling for the same amount of time.

$$R_{Z_1} = R_{Z_2}$$

$$T_{Z_2} = T_{Z_1} + \frac{d}{\Delta V}$$

We consider that the zoom commands for these fighters are given independently by GCI. Detection will be considered uncorrelated except that in the optical mode the detection capability of the second fighter will be enhanced.

Run two cases (one for each fighter) with same vectoring errors but with different errors on R_Z . Retain trial outcomes

$$P_{K_{T_i}} = X_{1_i} P_{K/L} + (1 - X_{1_i} P_{K/L}) X_{2_i} P_{K/L}$$

$$P_K = \frac{\sum_{i=1}^{N_T} P_{K_{T_i}}}{N_T}$$

c. Simultaneous Zoom

This case is treated in the same manner as II B except that the nominal ranges at zoom for the two fighters are different.

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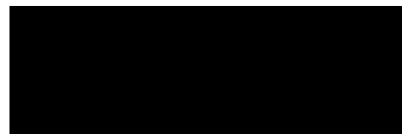
$$T_{Z_1} = T_{Z_2}$$

$$R_{Z_2} = R_{Z_1} + d$$

In this case the second fighter in general will be at the flight ceiling for a longer period of time than the first fighter.

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REQUIRES 3 RUNS (1 FOR P_{KF} AND 2 FOR P_{KNF})
 $P_K = P_{SF} P_{KF} + (1 - P_{SF}) P_{KNF}$

#1

REQUIRES 3 RUNS (1 FOR P_{KF} AND 2 FOR P_{KNF})
 $P_K = P_{SF} P_{KF} + (1 - P_{SF}) P_{KNF}$

#2

REQUIRES 2 RUNS
 $P_K = \frac{1}{N_T} \sum_{i=1}^{N_T} P_{KT_i}$

#3

REQUIRES 4 RUNS (2 FOR P_{KF} AND 2 FOR P_{KNF})
 $T_{Z_2} = T_{Z_1} + \frac{d}{V_2}$
 $R_{Z_2} = R_{Z_1} - \Delta V \left(\frac{d}{V_2} \right)$
 $P_K = P_{SF} P_{KNF} + (1 - P_{SF}) P_{KNF}$

#4

REQUIRES 2 RUNS
 $T_{Z_2} = T_{Z_1} + \frac{d}{\Delta V}$
 $R_{Z_1} = R_{Z_2}$
 $P_K = \frac{1}{N_T} \sum_{i=1}^{N_T} P_{KT_i}$

#5

REQUIRES 2 RUNS
 $R_{Z_2} = R_{Z_1} + d$
 $T_{Z_1} = T_{Z_2}$
 $P_K = \frac{1}{N_T} \sum_{i=1}^{N_T} P_{KT_i}$

#6

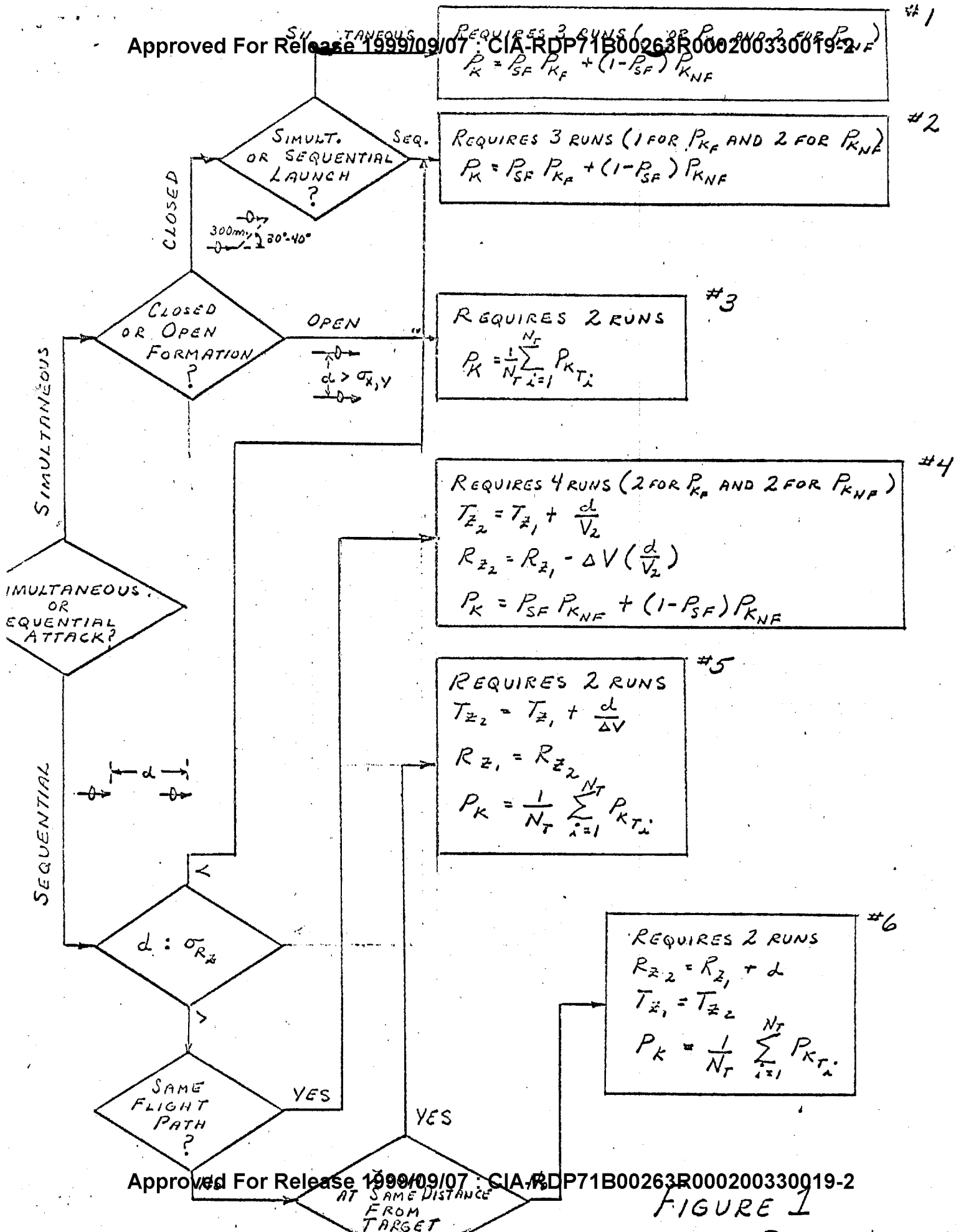


FIGURE 1